Effect of Roller Geometry on Roller Bearing Load-Life Relation

Fred B. Oswald
NASA Glenn Research Center

Erwin V. Zaretsky
NASA Glenn Research Center

Joseph V. Poplawski
Poplawski & Associates

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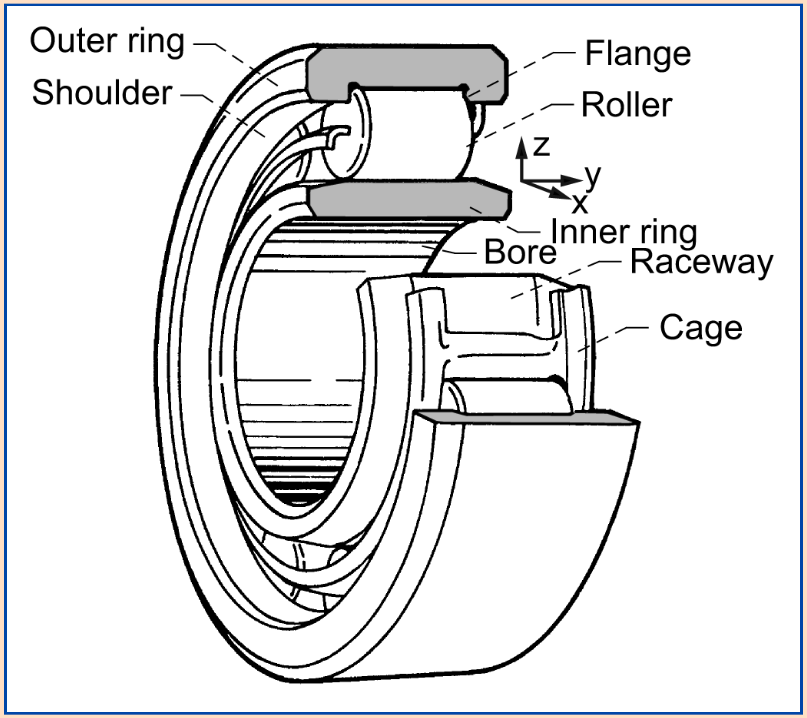
Life Modeling of Roller Bearings

Roller Bearing Schematic



Roller bearing life analysis is based on Lundberg-Palmgren (1947 & 1952) for uncrowned rollers.

Issue: What is effect of roller crowning on life & reliability?

Life Modeling of Roller Bearings

Lundberg-Palmgren (1947) rolling bearing life relation:

$$L \sim \left(\frac{1}{\tau}\right)^{c/m} \left(\frac{1}{V}\right)^{1/m} (z)^{h/m} \sim \left(\frac{1}{S_{\max}}\right)^{n} \sim \left(\frac{1}{P}\right)^{p}$$

where:

L = Life
τ = Critical shear stress
c = shear stress-life exponent
m = Weibull slope exponent
V = Stressed volume
z = Depth to crit. shear stress
h = Exponent

S_{max} = Max. Hertz stress
n = Exponent
P = Radial load
p = Load-life

with LP model, n = 8 and p = 4 for line contact

Life Modeling of Roller Bearings

Lundberg & Palmgren (1947) radial bearing load-life relation:

$$L = \left(\frac{C}{P}\right)^p$$

where:

L **= Life**
C **= Dynamic load capacity**
P **= Applied radial load**

exponent
p **= 3 for either ball bearings or roller bearings**

This relation was semi-empirical – based on life tests

Life Modeling of Roller Bearings

Lundberg & Palmgren (1952) revised cylindrical roller bearing load-life relation:

$$L = \left(\frac{C}{P}\right)^p$$

p **= 3 for pure point contact with both rings**

p **= 4 for pure line contact with both rings**

p **= 10/3 = 3.33 for mixed point and line contact**

ANSI/ABMA and ISO Standards use ***p*** **= 3.33 for roller bearings**

Life Modeling of Roller Bearings

Zaretsky (1996) modified the LP life equation, eliminating $[1/z]^h$

$$L \sim \left(\frac{1}{\tau}\right)^c \left(\frac{1}{V}\right)^{1/m} \sim \left(\frac{1}{S_{\max}}\right)^n \sim \left(\frac{1}{P}\right)^p$$

where:

- L = Life
- τ = Critical shear stress
- C = shear stress-life exponent
- m = Weibull slope
- V = Stressed volume
- S_{max} = Max. Hertz stress
- n = Exponent
- p = Load-life exponent

with Zaretsky model, n = 10 and p = 5 for line contact

Zaretsky model better fits post-1960, vacuum-processed steels

Objectives

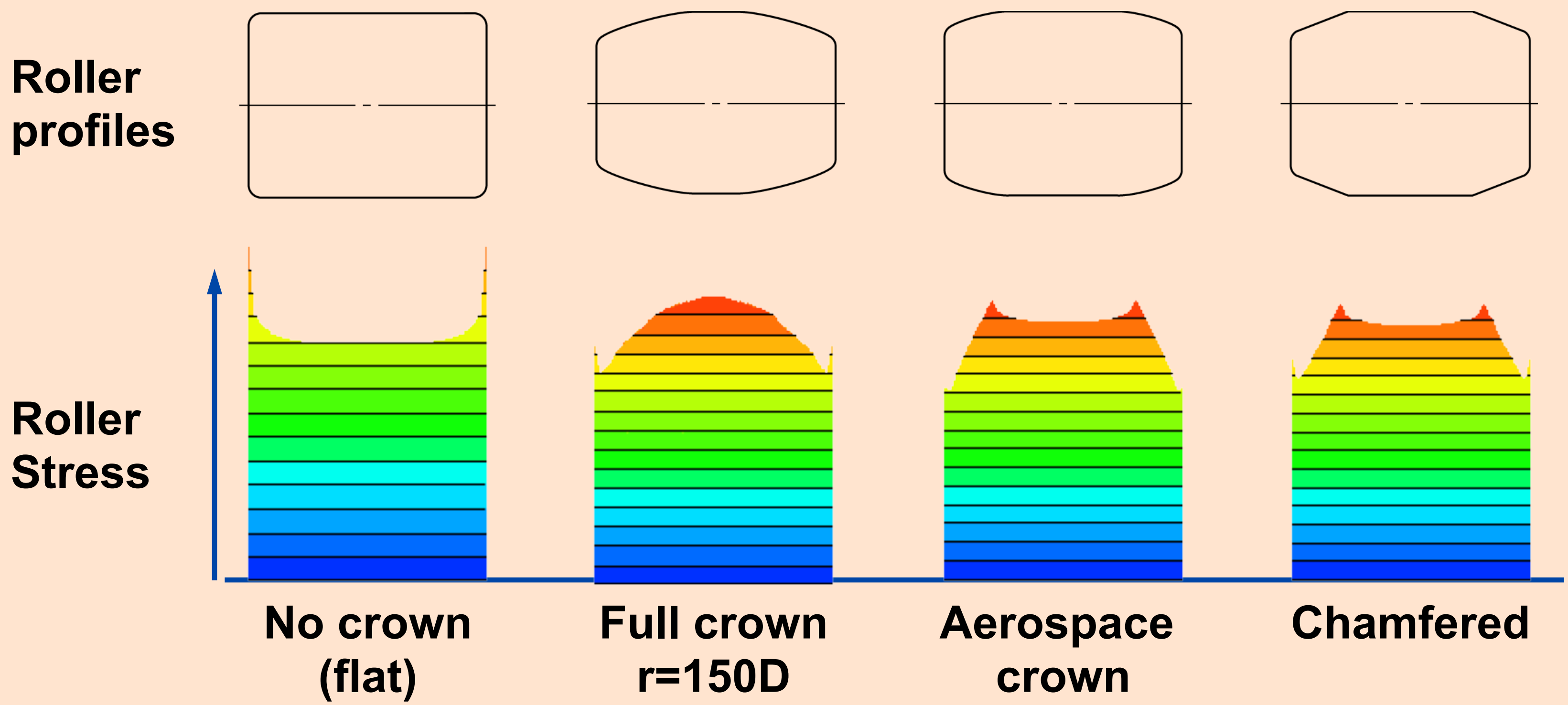
- **Investigate effect of roller profiles on load/life and stress/life relation for cylindrical roller bearings**
  - **Flat (uncrowned)**
  - **Aerospace crown**
  - **Chamfered**
  - **Full crown, r = 150D**
  - **Full crown, r = 100D**

Results based on 210-size cylindrical roller bearing:
Bore 50 mm, OD 90 mm, width 20 mm, roller dia. & length = 13 mm

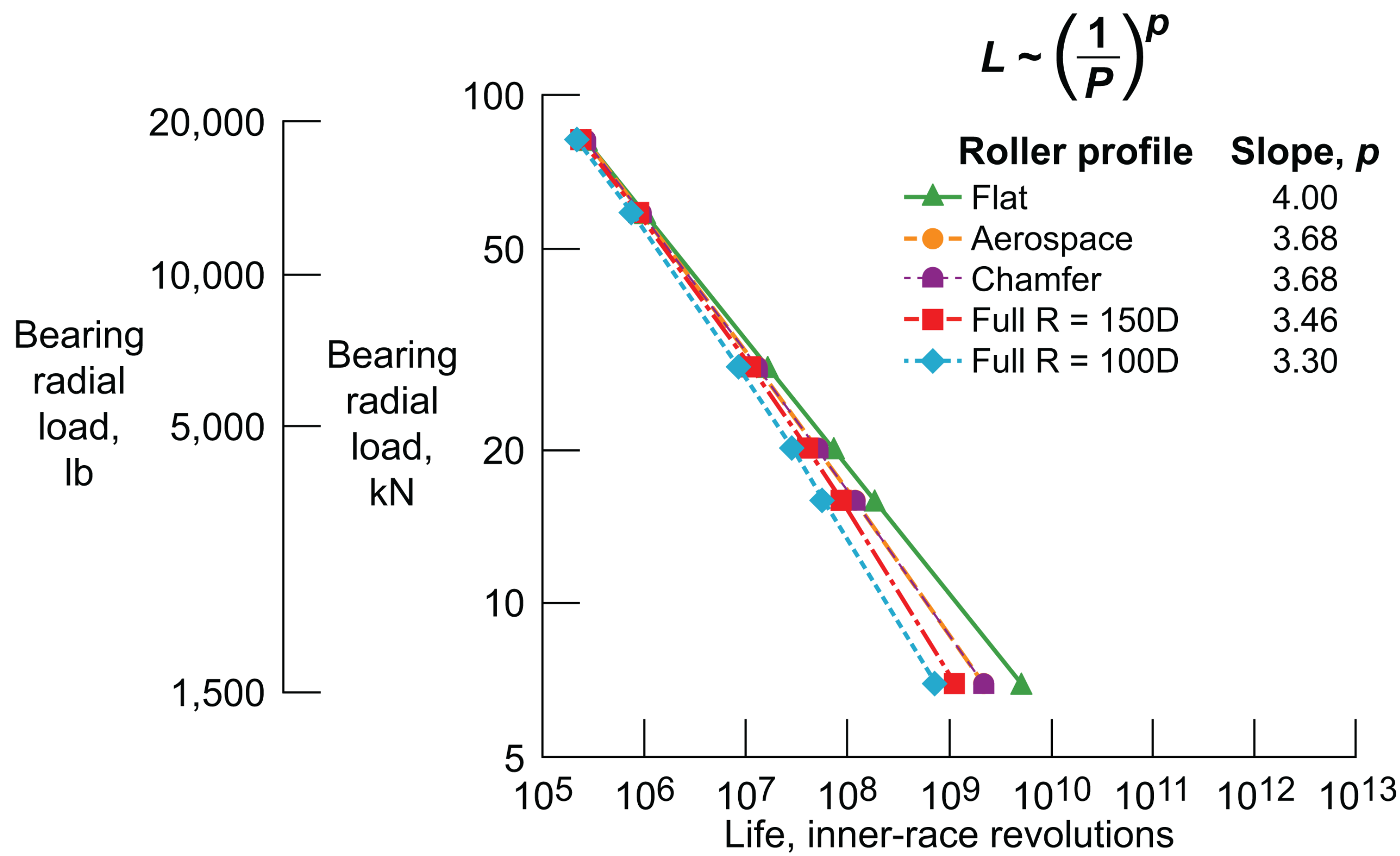
Life Modeling of Roller Bearings

Roller stress distribution for various cylindrical roller bearing roller profiles.

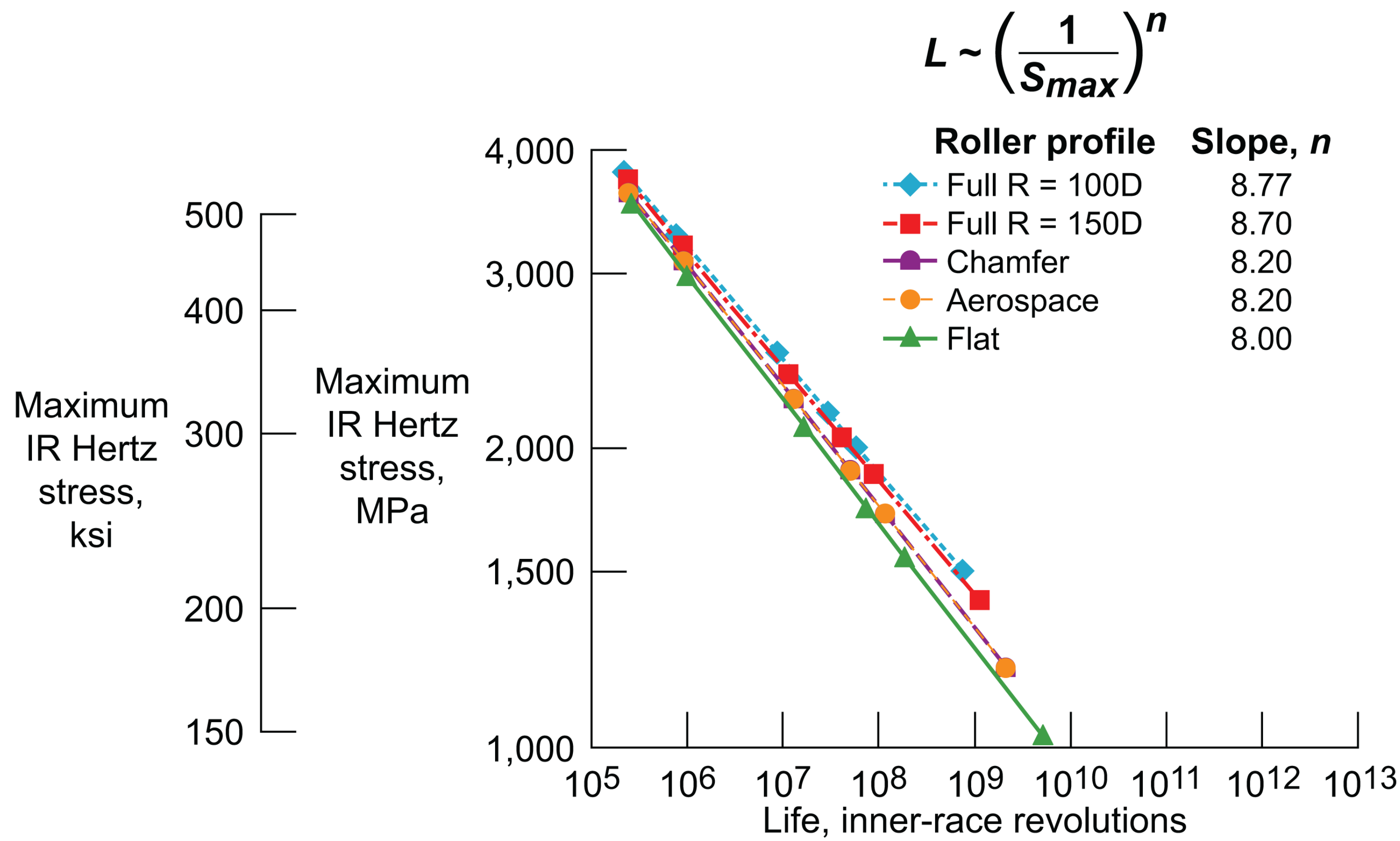
Roller crowning is used to minimize roller edge stress.



Load-Life Relation - Lundberg-Palmgren Model



Hertz Stress-Life Relation - Lundberg-Palmgren Model



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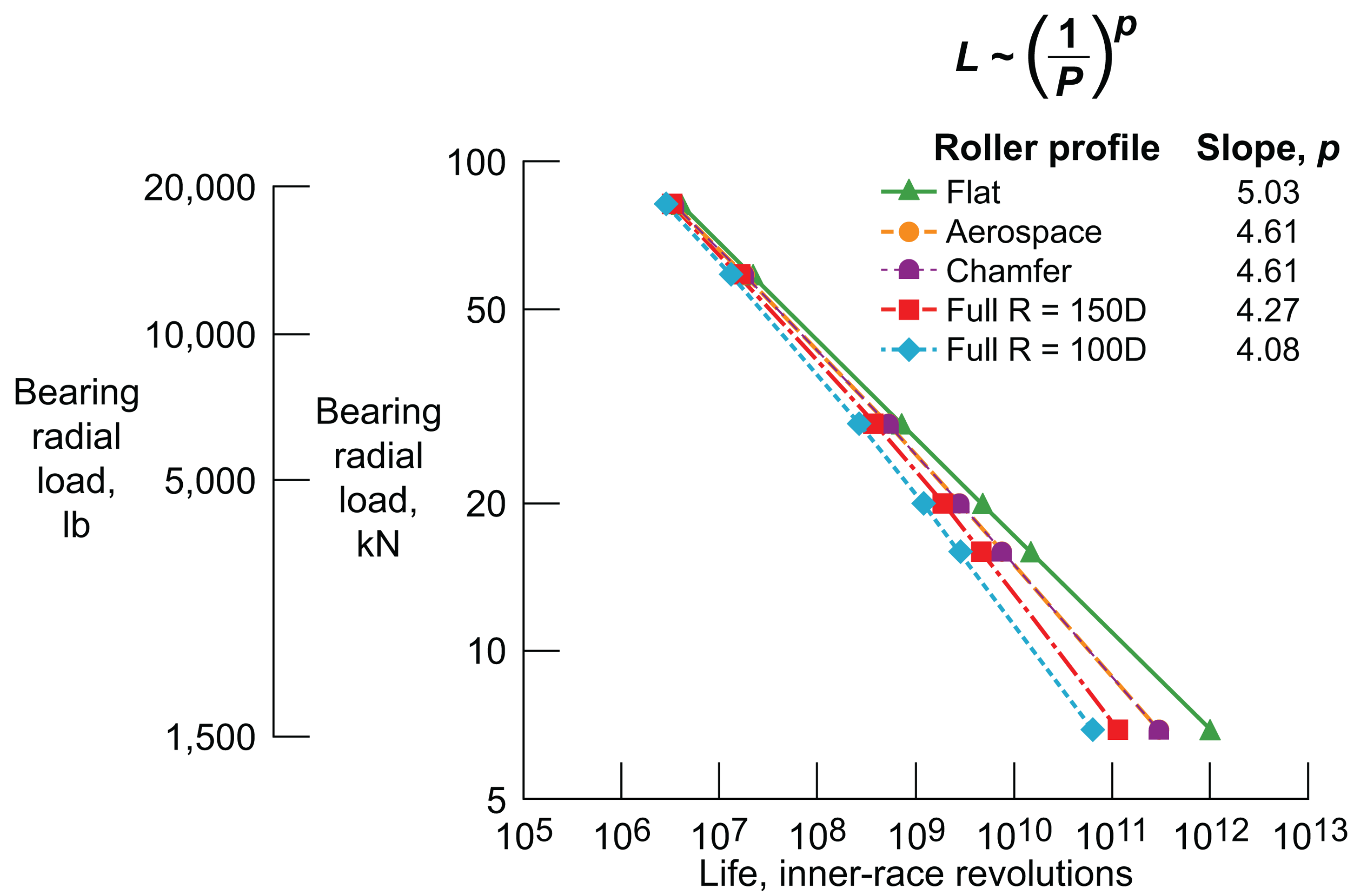
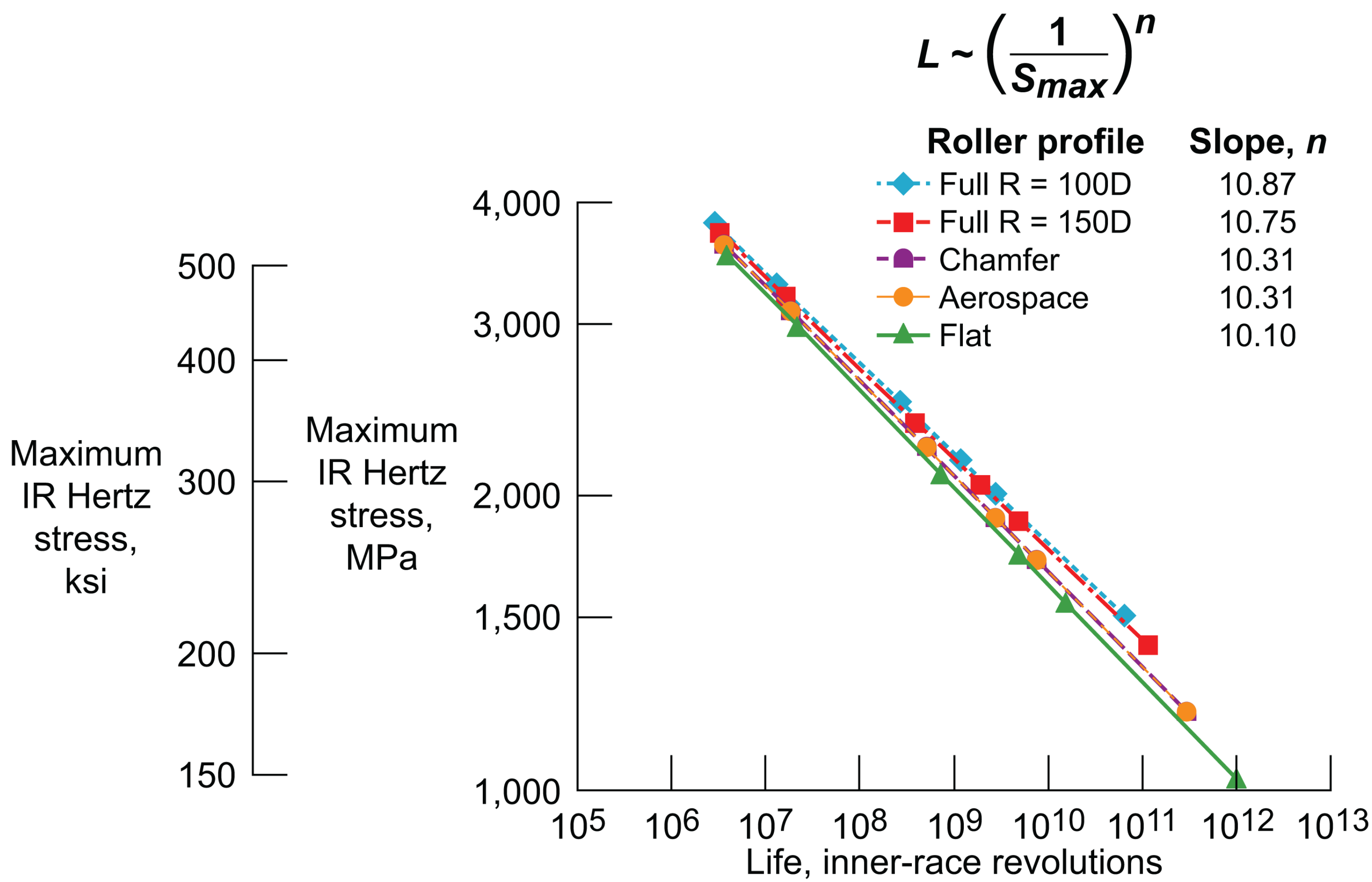
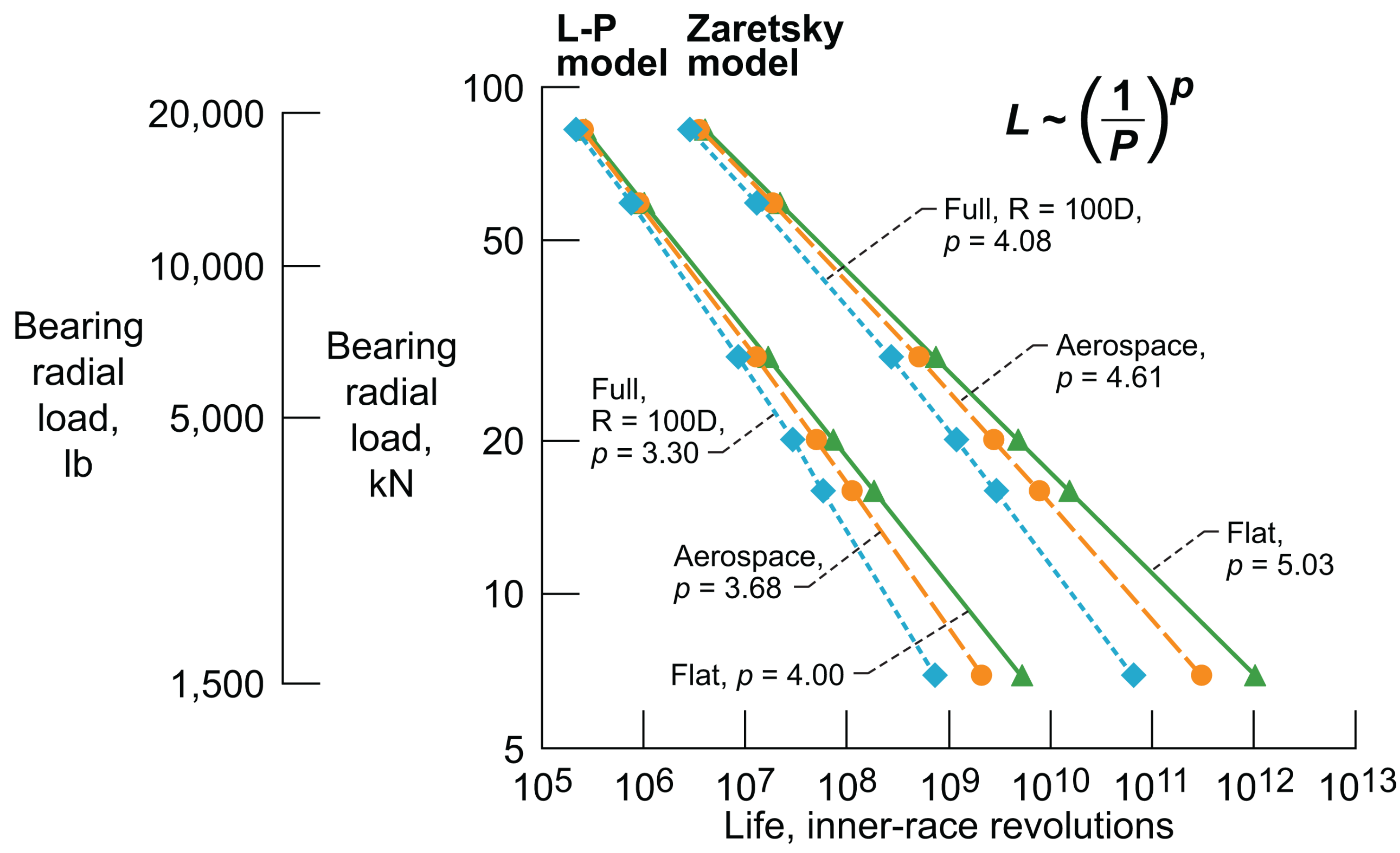
Load-Life Relation - Zaretsky Model



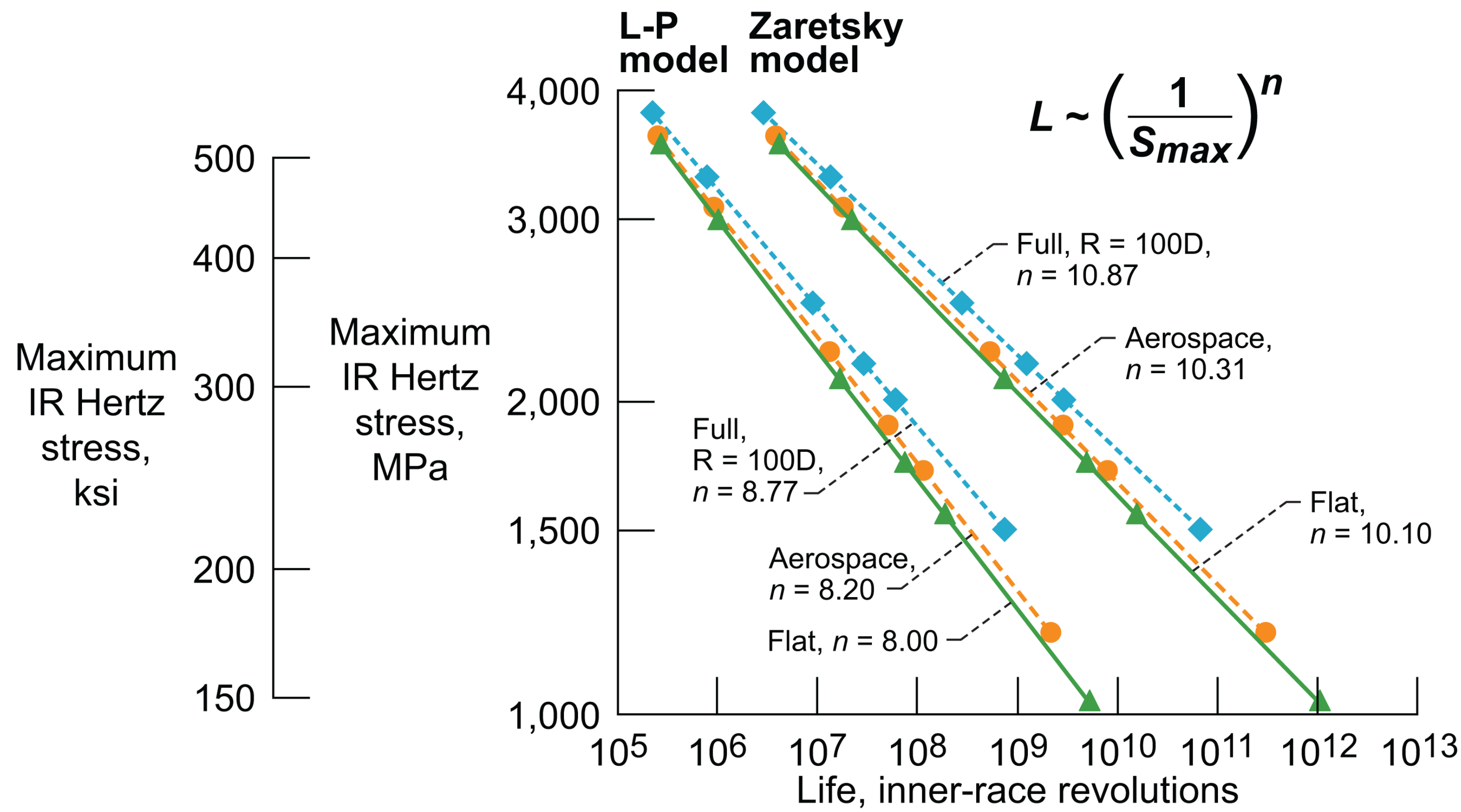
Hertz Stress-Life Relation - Zaretsky Model



Comparison of Lundberg-Palmgren and Zaretsky Models



Comparison of Lundberg-Palmgren and Zaretsky Models



Comparison of Lundberg-Palmgren and Zaretsky Models

Relative Life = 1.0 for C/P = 4.7 for flat roller
where S_{max} = 1556 MPa (226 ksi)

Roller Profile	Lundberg-Palmgren			Zaretsky		
	p	*n*	Rel. Life	*p*	*n*	Rel. Life
Flat	4.00	8.00	1.0	5.03	10.10	83
Aero. & Chamfer	3.68	8.20	0.6	4.61	10.31	43
Full, R=150D	3.46	8.70	0.5	4.27	10.75	27
Full, R=100D	3.30	8.77	0.3	4.08	10.87	16
Full, R=50D	3.10	8.77	0.2	3.82	10.84	6

R = crown radius of curvature
D = roller diameter

Summary of Results

- For Flat rollers, Zaretsky load-life exponent $p = 5$ compared to $p = 4$ for LP model
- Confirmed LP model for Full Crown $p = 3.33$ Zaretsky model for Full Crown $p = 4.3$
- Aerospace or Chamfered Crown $p = 3.7$ for LP model and $p = 4.6$ for Zaretsky model
- Zaretsky model predicts life 83 times higher than LP model for flat rollers at moderate load

Published Hertz Stress-Life Data